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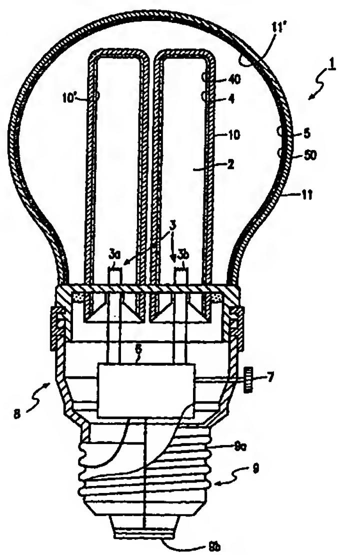
(54) Title: LOW-PRESSURE MERCURY DISCHARGE LAMP

(57) Abstract

A low-pressure mercury discharge lamp of the invention comprises an envelope (1) that encloses a discharge space (2) in a gastight manner. The envelope is provided with a luminescent material (4) which is excitable with radiation of a wavelength of 254 nm. The envelope (1) is further provided with a further luminescent material (5) which has an excitation spectrum of which the value for a wavelength of 436 nm amounts to at least 10 % of that at a wavelenght of 254 nm, and which further luminescent material has an emission spectrum with a maximun in a wavelength range from 580 to 720 nm. The lamp of the invention has in a dimmed state of operation a color point of which the value of the x-coordinate is higher than in the nominal state of operation.



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Low-pressure mercury discharge lamp.

The invention relates to a low-pressure mercury discharge lamp comprising a light-transmitting envelope which encloses a discharge space in a gastight manner, which discharge space is provided with an ionizable filling of mercury as well as one or several rare gases, and further comprising means for maintaining an electric discharge in the discharge space, said envelope being provided with a luminescent material which is excitable by means of radiation having a wavelength of 254 nm.

Such a low-pressure mercury discharge lamp is known from EP 660 371 A1. The envelope enclosing the discharge space of the known lamp is a tubular discharge vessel in which electrodes are positioned at both ends so as to serve as the means for maintaining a discharge in the discharge space. The discharge vessel is provided with a luminescent layer at a surface facing towards the interior, with a luminescent material comprising the luminescent substances: cerium-magnesium aluminate activated by trivalent terbium, barium-magnesium aluminate activated by bivalent europium, and yttrium oxide activated by trivalent europium. The known lamp serves as a replacement for an incandescent lamp. It is a disadvantage that this lamp in a dimmed operational state has a color point whose x-coordinate value is lower than it is during nominal operation. The known lamp differs from an incandescent lamp in this respect; indeed, the value of the x-coordinate of the color point in the dimmed operational state of an incandescent lamp is higher than it is in the nominal operational state.

It is an object of the invention to provide a low-pressure mercury discharge lamp of the kind described in the opening paragraph whose x-coordinate value of the color point in the dimmed operational state is higher than it is in the nominal operational state. According to the invention, the low-pressure mercury discharge lamp of the kind described in the opening paragraph is for this purpose characterized in that the envelope is in addition provided with a further luminescent material which has an excitation spectrum whose value

for a wavelength of 436 nm amounts to at least 10% of that for a wavelength of 254 nm, said further luminescent material having an emission spectrum with a maximum in a wavelength range from 580 to 720 nm.

The inventor has found that the intensity of the radiation with a wavelength of 436 nm generated in the discharge space decreases less strongly than that of 254 nm radiation when the lamp is dimmed. The radiation having the former wavelength is converted into radiation lying in a wavelength range from 580 to 720 nm in the lamp according to the invention. The lamp according to the invention thus has a color point in the dimmed operational state whose x-coordinate has a higher value than in the nominal operational state.

It is noted that a low-pressure mercury discharge lamp is known from US-P 5,592,052 whose envelope is provided with a luminescent material which is excitable by means of radiation having a wavelength of 254 nm and with a further luminescent material which is excitable by means of radiation having a wavelength in the range from 330 to 440 nm. The combination of these luminescent materials aims to achieve that the color temperature of the lamp can be adjusted by means of the manner of operation. The color temperature of the known lamp rises when the known lamp is operated in the pulse burst mode instead of continuously. The luminous flux decreases at the same time with this change in the manner of operation. This is undesirable when a low-pressure mercury discharge lamp is used as a replacement for an incandescent lamp. Incandescent lamps by contrast have the property that the color temperature falls when the luminous flux is set for a lower value. In an embodiment of the lamp known from US-P 5,592,052, the further luminescent material is formed by the luminescent substance $YVO_4:Eu^{3+}$. This luminescent material is not or hardly excitable by means of radiation having a wavelength of 436 nm.

The further luminescent material of the lamp according to the invention may comprise a single luminescent substance or may be composed of several luminescent substances. Suitable luminescent substances for the further luminescent material are, for example, $CaS:Eu^{2+}$, $SrS:Eu^{2+}$ or $(Zn,Cd)S:Ag^{+}$, or an organic luminescent material such as Eu cinnamate.

In an attractive embodiment of the low-pressure mercury discharge lamp according to the invention, the maximum of the emission spectrum of the further luminescent material lies between 630 nm and 700 nm. The further luminescent material then contributes to the color rendering index R9 (deep red). The luminescent substance $Mg_4GeO_{5.5}F:Mn^{4+}$, for example, is suitable for this.

The degree to which the value of the x-coordinate of the color point rises when the lamp is dimmed can be influenced by the degree to which the further luminescent material absorbs the 436 nm radiation. In a practical embodiment, the further luminescent material absorbs 20 to 70% of the radiation having a wavelength of 436 nm generated in the discharge space. The effect of the measure is comparatively small for values lower than 20%. Values above 70% in general lead to a comparatively strong absorption also of the radiation generated by the luminescent material. The degree of absorption may be readily chosen by those skilled in the art. For example, the further luminescent material may be provided in a suspension. A higher percentage by weight of the further luminescent material in the suspension will lead to a higher coating weight and thus to a stronger absorption. The luminescent material may consist of a single luminescent substance which emits over a wide wavelength range or a single luminescent substance which emits in different wavelength ranges. Alternatively, the luminescent material may be composed of different luminescent substances which emit in mutually differing wavelength ranges.

The luminescent material may comprise, for example, one or several of the luminescent substances $Ce_{0.67}Tb_{0.33}MgAl_{11}O_{19}$ (CAT), $Ce_{0.3}Gd_{0.5}Tb_{0.2}MgB_5O_{10}$ (CBT) for emission in a wavelength range from 520 to 565 nm. Tb^{3+} here performs the role of activator. If a comparatively high nominal color temperature is desired, the luminescent material may in addition comprise one or several of the luminescent substances $(Ba,Ca)_{1.29}Al_{12}O_{19.29}:Eu^{2+}$ (BAL), $Sr_5(PO_4)_3Cl:Eu^{2+}$ (SCAP), $BaMgAl_{10}O_{17}:Eu^{2+}$ (BAM), and $Sr_2Al_6O_{11}:Eu^{2+}$ (SAL) for emission in a wavelength range from 430 to 490 nm. The radiation in this wavelength range may be entirely realized by direct emission of the mercury discharge, in particular the 436 nm line, in lamps having a comparatively low nominal color temperature. The further luminescent material contributes to the wavelength range from 580 to 720 nm in the spectrum. If so desired, a luminescent substance may be present in the luminescent material which makes an additional contribution to this wavelength range, such as $Y_2O_3:Eu^{3+}$ (YOX).

In an embodiment of the lamp according to the invention, the envelope is a discharge vessel which is closed in a vacuumtight manner, while the luminescent material and the further luminescent material are jointly provided in a luminescent layer. An attractive embodiment is characterized in that the luminescent material and the further luminescent material are provided in mutually differing luminescent layers, the luminescent layer comprising the luminescent material being arranged between the discharge space and the luminescent layer comprising the further luminescent material. This has the advantage that

UV radiation generated in the discharge space has already been largely converted in the luminescent layer comprising the luminescent material before it can reach the luminescent layer comprising the further luminescent material. In addition, the luminescent material here protects the further luminescent material against bombardment with ions and electrons from the discharge space. This widens the range of options from which the further luminescent material can be chosen.

In a modification of the above attractive embodiment, the luminescent layers are provided on the surface of the discharge vessel facing to the interior, such that the luminescent layer comprising the further luminescent material supports the luminescent layer comprising the luminescent material. A favorable modification of said attractive embodiment of the lamp according to the invention is characterized in that the envelope comprises not only a discharge vessel which is closed in a vacuumtight manner but also an outer bulb which surrounds the discharge vessel, said discharge vessel supporting a luminescent layer comprising the luminescent material on a surface facing towards the interior and the outer bulb supporting a luminescent layer comprising the further luminescent material. The luminescent layer comprising the further luminescent material then serves at the same time as a diffusor for the light generated by the luminescent layer comprising the luminescent material. The outer bulb may be made from glass, or alternatively from a synthetic resin. It is obviously sufficient in those embodiments in which the envelope consists of several parts for only one of these parts, for example the discharge vessel or the outer bulb, of the envelope to be closed in a gastight manner.

It is self-evident that the nature of the means for maintaining the discharge is immaterial to the essence of the invention. Said means may be constructed, for example, as a pair of electrodes which may or may not be positioned inside the discharge vessel. Alternatively, the means may be constructed, for example, as a coil with which an alternating magnetic field is generated in the discharge space during operation. The coil is preferably positioned outside the discharge space because electrical lead-through elements through the discharge vessel are thus avoided.

These and other aspects of the invention will be explained in more detail with reference to a drawing, in which:

Fig. 1 shows a first embodiment of the low-pressure mercury discharge lamp according to the invention,

Fig. 2 shows the emission spectrum of the further luminescent material used in the lamp of Fig. 1,

Fig. 3A shows the excitation spectrum of this further luminescent material,

Fig. 3B shows the excitation spectrum of another luminescent material,

Fig. 4 shows the difference (Δx, Δy) in color point during dimmed operation versus nominal operation, and

Fig. 5 shows a second embodiment of the low-pressure mercury discharge lamp according to the invention.

The first embodiment of the low-pressure mercury discharge lamp shown in Fig. 1 comprises a light-transmitting envelope 1 which encloses a discharge space 2 in a gastight manner, which discharge space is provided with an ionizable filling comprising mercury and one or several rare gases. The lamp shown further comprises means 3 for maintaining an electric discharge in the discharge space 2. The envelope 1 is provided with a luminescent material 4 which is excitable by means of radiation having a wavelength of 254 nm. The luminescent material 4 here comprises the luminescent substances $Ce_{0.67}Tb_{0.33}MgAl_{11}O_{19}$, and $Y_2O_3{:}Eu^{3+}$ in a weight ratio of 23:77. The envelope 1 is in addition provided with a further luminescent material 5 which has an excitation spectrum whose value for a wavelength of 436 nm is at least 10% of that for a wavelength of 254 nm, while the emission spectrum has a maximum in a wavelength range from 580 to 720 nm.

The further luminescent material 5 in this case comprises the luminescent material $Mg_4GeO_{5.5}F{:}Mn^{4+}$ whose emission spectrum has a maximum which lies between 630 nm and 700 nm, i.e. at approximately 660 nm.

The envelope 1 in the embodiment shown comprises several parts, i.e. a discharge vessel 10 which is closed in a vacuumtight manner and an outer bulb 11. The discharge vessel 10 is constructed as a tube which is bent into a hook shape and which has an internal diameter of 10 mm. An electrode 3a, 3b is arranged in the tube at each end. The electrodes 3a, 3b form the means 3 for maintaining an electric discharge in the discharge space 2. The outer bulb 11 surrounds the discharge vessel 10.

The low-pressure mercury discharge lamp shown here forms part of a lighting unit which in addition comprises a supply unit 6 which can be controlled with a controller 7. The supply unit 6 is accommodated in a housing 8 and connected to contacts 9a, 9b of a lamp cap 9 attached to the housing 8.

The luminescent material 4 and the further luminescent material 5 are provided in mutually differing luminescent layers 40 and 50, respectively. The luminescent layer 40 comprising the luminescent material 4 is present between the discharge space 2 and the luminescent layer 50 comprising the further luminescent material 5. The discharge vessel 10 here supports the luminescent layer 40 with the luminescent material 4 at a surface 10' facing towards the interior. The outer bulb 11 supports the luminescent layer 50 with the further luminescent material 5, here again at a surface 11' which faces towards the interior.

Fig. 2 shows the emission spectrum of $Mg_4GeO_{5.5}F:Mn^{4+}$. The emission has a maximum at a wavelength of 660 nm. The excitation spectrum of this luminescent substance used in the further luminescent material is shown in Fig. 3A. It is apparent therefrom that the value of the excitation spectrum of the further luminescent material at a wavelength of 436 nm amounts to 48% of that at 254 nm. Fig. 3B shows the excitation spectrum of $YVO_4:Eu^{3+}$, for comparison, from which it appears that the value of the excitation spectrum of this luminescent substance at a wavelength of 436 nm is negligibly small compared with that at a wavelength of 254 nm.

Two lamps (inv1, inv2) according to the embodiment of the invention shown in Fig. 1 and one lamp (ref) not according to the invention were manufactured. The luminescent layer 50 comprising the further luminescent material 5 absorbs 39 and 61% of the radiation having a wavelength of 436 nm in the lamps inv1 and inv2, respectively. The absorption lies between the limits of 20% and 70% mentioned above in both cases. The luminescent layer 50 with the further luminescent material 5 was obtained in that a suspension comprising the luminescent substance $Mg_4GeO_{5.5}F:Mn^{4+}$ with butyl acetate as a suspension agent and nitrocellulose as a binder was caused to flow over the inner surface of the outer bulb and dried, whereupon the binder was driven from the luminescent layer 50 by heating. The quantities by weight of said luminescent substance in the suspension were 1.39 and 1.48 g/cm^3 in the lamps inv1 and inv2, respectively. An outer bulb was absent in the lamp ref.

The lamps ref, inv1, and inv2 were operated in the nominal and in the dimmed state consecutively. In the nominal operational state, the power P dissipated by the lamp is 8.5 W, in the dimmed state 3.4 W. The luminous flux values of the lamps in the dimmed state were approximately 15% of those in the nominal operational state. The following Table lists the color temperature T_c and the coordinates x, y of the color points of said lamps in both operational states.

P(W)	ref			inv1			inv2		
	T_c(K)	x	y	T_c(K)	x	y	T_c(K)	x	y
8.5	2778	457	416	2710	473	436	2653	485	448
3.4	2699	454	400	2579	475	421	2537	489	438

Fig. 4 shows with arrows the change (Δx, Δy) of the color point in a transition from the nominal operational state to the dimmed operational state. It is apparent from Fig. 4 that the value of the x-coordinate of the color point in the dimmed operational state is higher than it is in the nominal operational state for the lamps inv1 and inv2 according to the invention. For the lamp ref not according to the invention, the x-coordinate of the color point in the dimmed operational state by contrast has a lower value than in the nominal operational state.

A second embodiment of the lamp according to the invention is shown in Fig. 5. Components therein corresponding to those in Fig. 1 have reference numerals which are 100 higher. The envelope 101 in this embodiment comprises an inner part 112 and an outer part 113. The inner part 112 is a tube bent into a U-shape with a first closed end 112a in which a first electrode 103a is arranged, and a second, open end 112b. The outer part 113 envelops the inner part 112 in a gastight manner. A second electrode 103b is arranged in the outer part opposite the open end 112b. A surface 112' facing inwards of the inner part 112 of the envelope 101 is provided with a luminescent material 104 which comprises the luminescent substances $BaMgAl_{11}O_{17}:Eu^{2+}$, $Ce_{0.67}Tb_{0.33}MgAl_{11}O_{19}$, and $Y_2O_3:Eu^{3+}$. The outer part 113 of the envelope 101 is provided with a further luminescent material 104 comprising the luminescent substance $CaS:Eu^{2+}$ on a surface 113' facing towards the interior.

Claims:

1. A low-pressure mercury discharge lamp comprising a light-transmitting envelope (1; 101) which encloses a discharge space (2; 102) in a gastight manner, which discharge space is provided with an ionizable filling of mercury as well as one or several rare gases, and further comprising means (3a, 3b; 103a, 103b) for maintaining an electric discharge in the discharge space, said envelope (1; 101) being provided with a luminescent material (4; 104) which is excitable by means of radiation having a wavelength of 254 nm, characterized in that the envelope (1; 101) is in addition provided with a further luminescent material (5; 105) which has an excitation spectrum whose value for a wavelength of 436 nm amounts to at least 10% of that for a wavelength of 254 nm, said further luminescent material having an emission spectrum with a maximum in a wavelength range from 580 to 720 nm.

2. A low-pressure mercury discharge lamp as claimed in claim 1, characterized in that the maximum of the emission spectrum of the further luminescent material (5) lies between 630 nm and 700 nm.

3. A low-pressure mercury discharge lamp as claimed in claim 1 or 2, characterized in that the further luminescent material (5) absorbs 20 to 70% of the radiation having a wavelength of 436 nm generated in the discharge space.

4. A low-pressure mercury discharge lamp as claimed in claim 1, 2 or 3, characterized in that the luminescent material (4) and the further luminescent material (5) are provided in mutually differing luminescent layers (40 and 50, respectively), the luminescent layer (40) comprising the luminescent material (4) being arranged between the discharge space (2) and the luminescent layer (50) comprising the further luminescent material (5).

5. A low-pressure mercury discharge lamp as claimed in claim 4, characterized in that the envelope (1) comprises a discharge vessel (10) which is closed in a vacuumtight manner and an outer bulb (11), which outer bulb (11) surrounds the discharge vessel, said

discharge vessel (10) supporting the luminescent layer (40) comprising the luminescent material (4) on a surface facing towards the interior and the outer bulb (11) supporting a luminescent layer (50) comprising the further luminescent material (5).

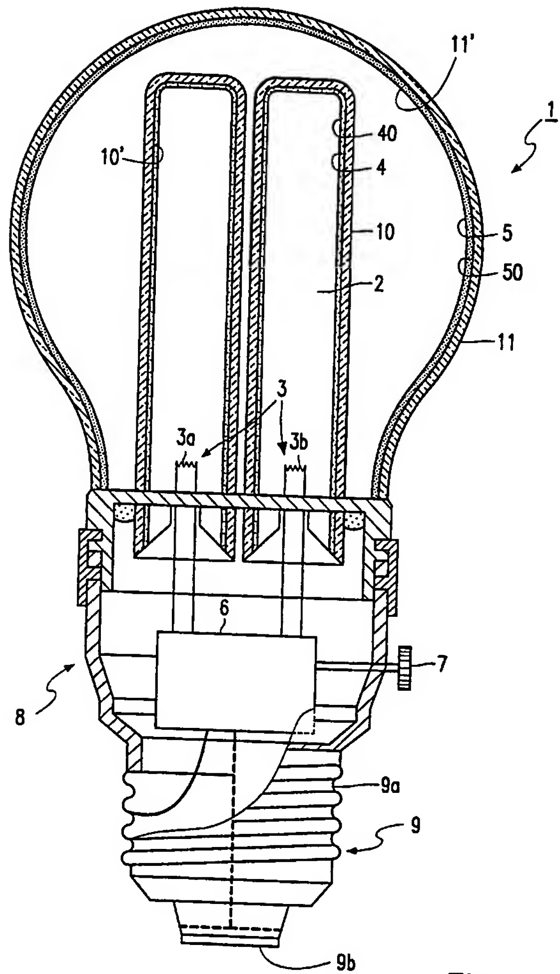


FIG. 1

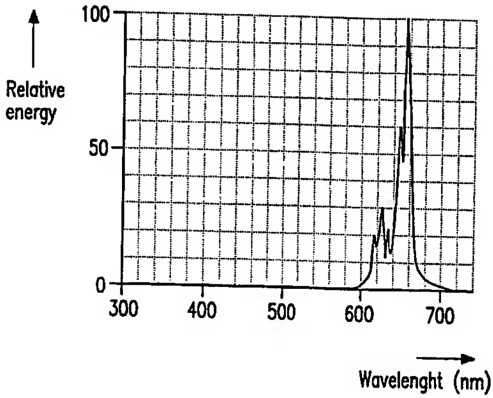
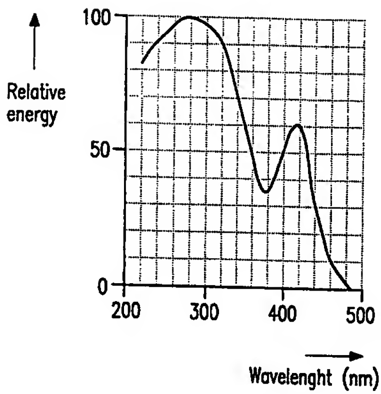

100
50
0
Relative energy
300
400
500
600
700
Wavelenght (nm)

FIG. 2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Relative energy
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300
400
500
Wavelenght (nm)

FIG. 3A

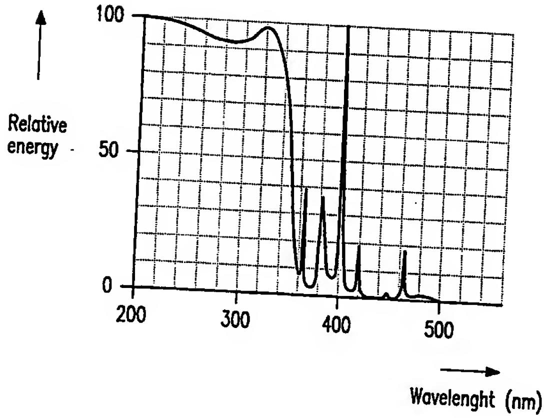
100
Relative
energy
50
0
200
300
400
500
Wavelenght (nm)

FIG. 3B

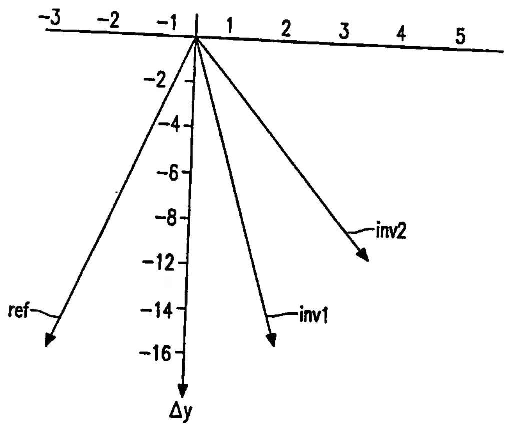
-3
-2
-1
1
2
3
4
5
-2
-4
-6
-8
-12
-14
-16
Δy
ref
inv1
inv2

FIG. 4

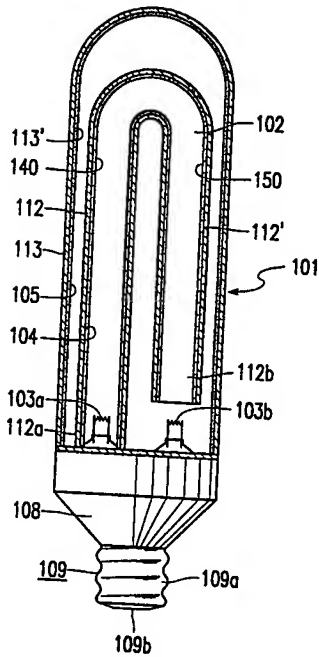
113'
140
112
113
105
104
103a
112a
108
109
102
150
112'
101
112b
103b
109a
109b

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 98/01567

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H01J 61/48 // C09K 11/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01J, H01B, C04B, C09K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	US 5525860 A (K. HORAGUCHI ET AL), 11 June 1996 (11.06.96) --	1
A	Patent Abstracts of Japan, abstract of JP 57-78764 A (HITACHI SEISAKUSHO K.K.), 17 May 1982 (17.05.82) --	
A	WO 9808916 A1 (PHILIPS ELECTRONICS N.V.), 5 March 1998 (05.03.98) --	

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18 March 1999	24 -03- 1999

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INTERNATIONAL SEARCH REPORT

Information on patent family members

02/03/99

International application No.
PCT/IB 98/01567

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